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(71) Applicant
Ferranti plc (United Kingdom),
 Bridge House, Park Road, Gatley, Cheadle, Cheshire

(72) Inventors
 Ian Richard Harris
 Ewan William Shepherd

(74) Agent and/or Address for Service
 A R Cooper,
 Patents & Legal Department, Bridge House, Park Road,
 Gatley, Cheadle, Cheshire

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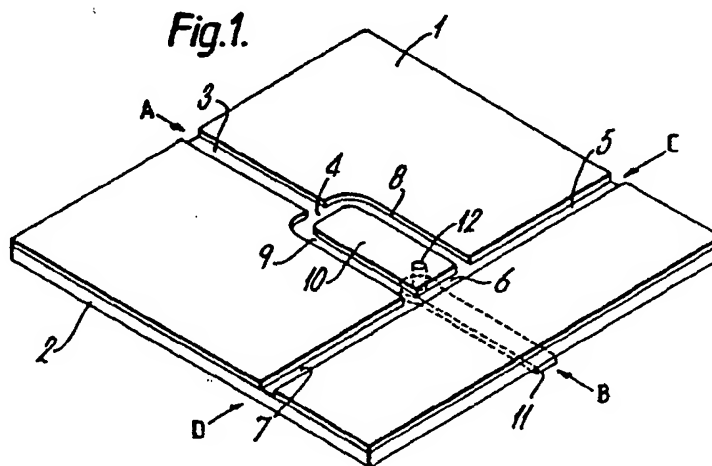
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 H1W

(54) Four-port microwave hybrid coupler

(57) A coupler is made from a layer (1) of conducting material carried on an insulating support (2). A first slotline (3) is formed in the conducting layer extending from a first input port (A). A second slotline (5, 7) is formed at right-angles to and spaced from the end (4) of the first slotline (3), extending between first and second output ports (C and D). Third and fourth slotlines (8, 9) extend from the end of the first slotline (3) to points on the second slotline spaced by a distance which is electrically short compared with one-quarter of a wavelength. The third and fourth slotlines (8, 9) are an odd multiple of quarter-wavelengths long. A stripline conductor (11) is formed on the other surface of the insulating support (2) and extends parallel to the first slotline (3) from a second input port (B) to an area directly opposite to that area (10) of the conducting layer between the second, third and fourth slotlines. In one embodiment an electrical connection (12) is formed between that end of the stripline and the area (10) of the conducting layer.



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Fig.1.

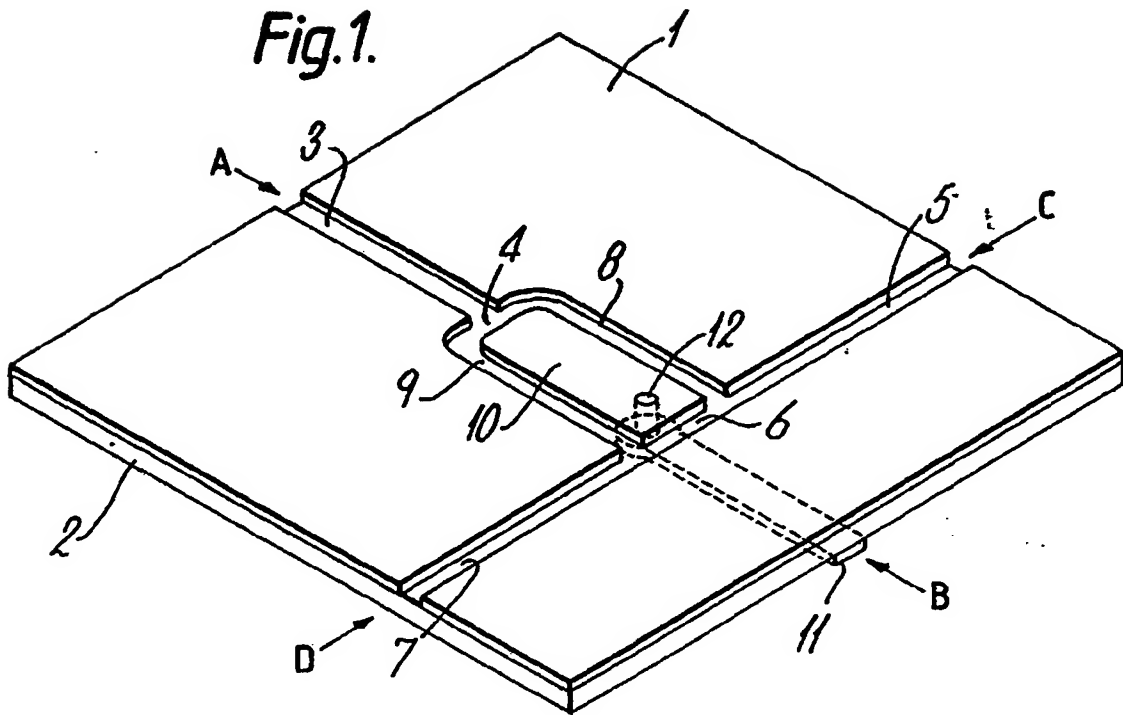


Fig.2.

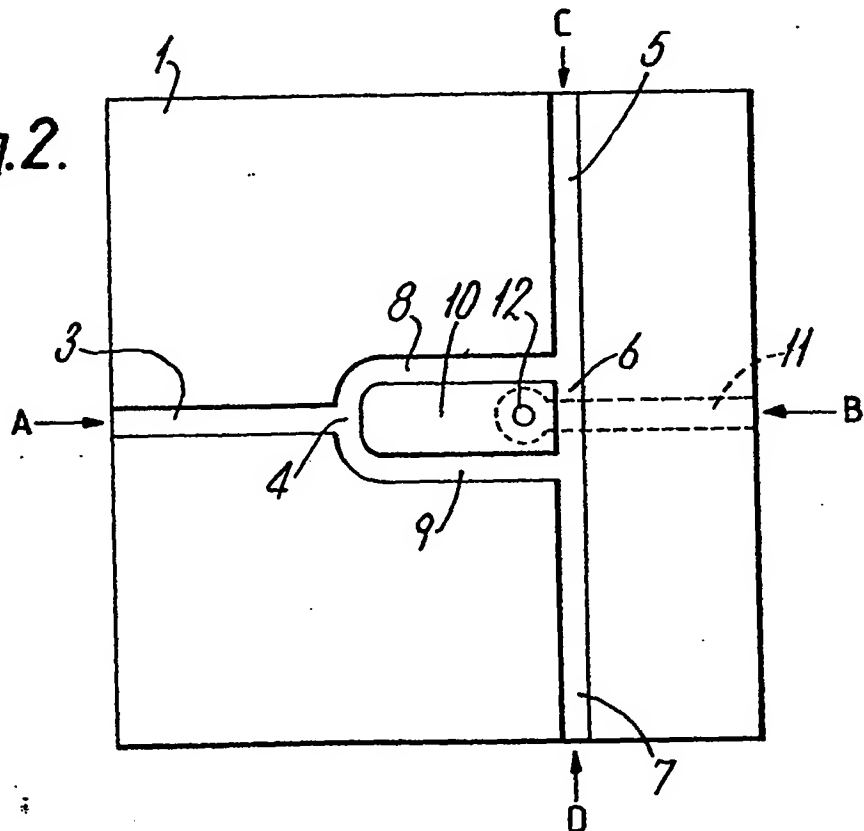


Fig. 3.

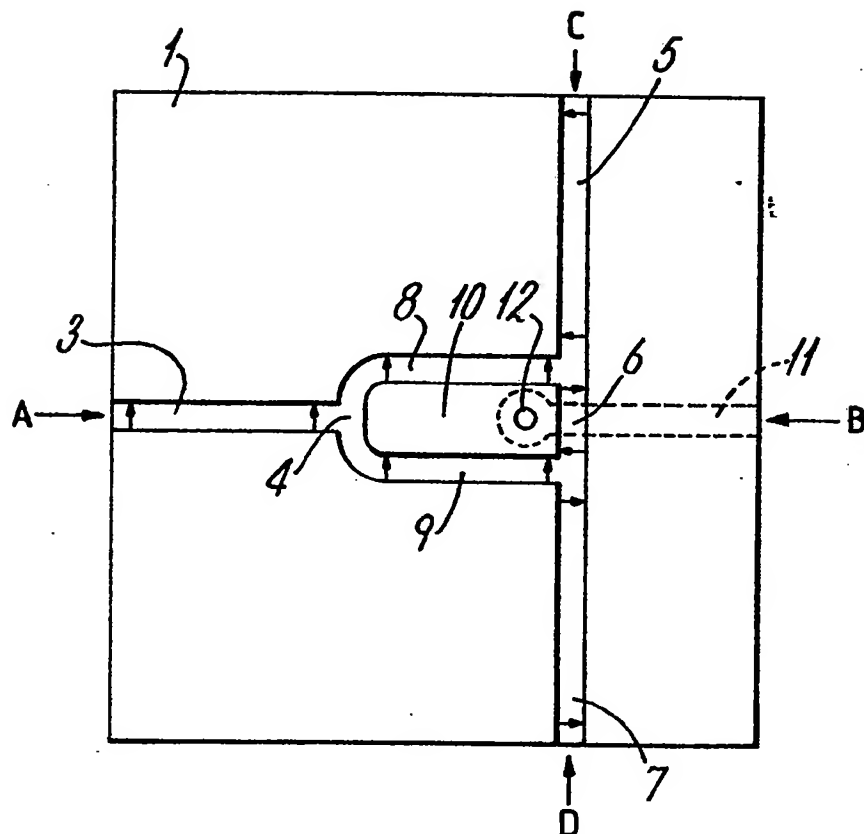
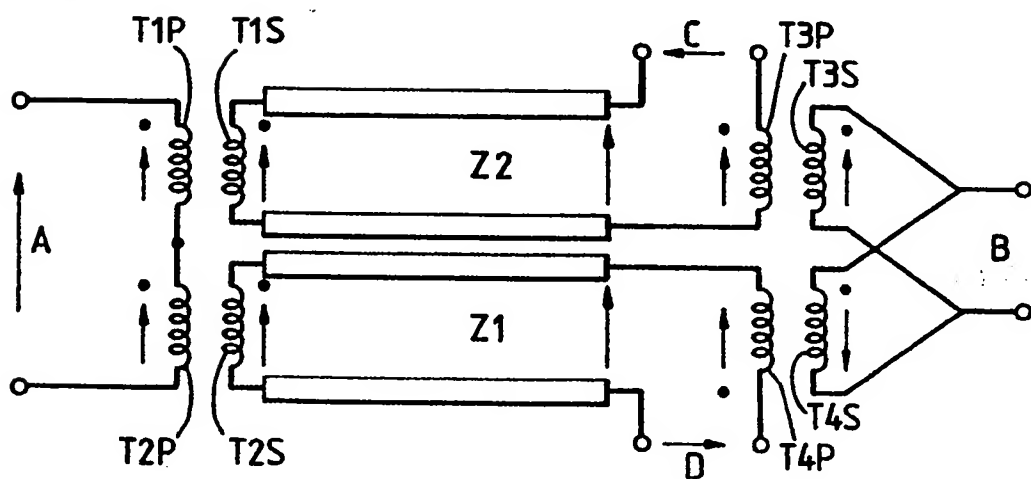


Fig. 4.



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Fig. 5.

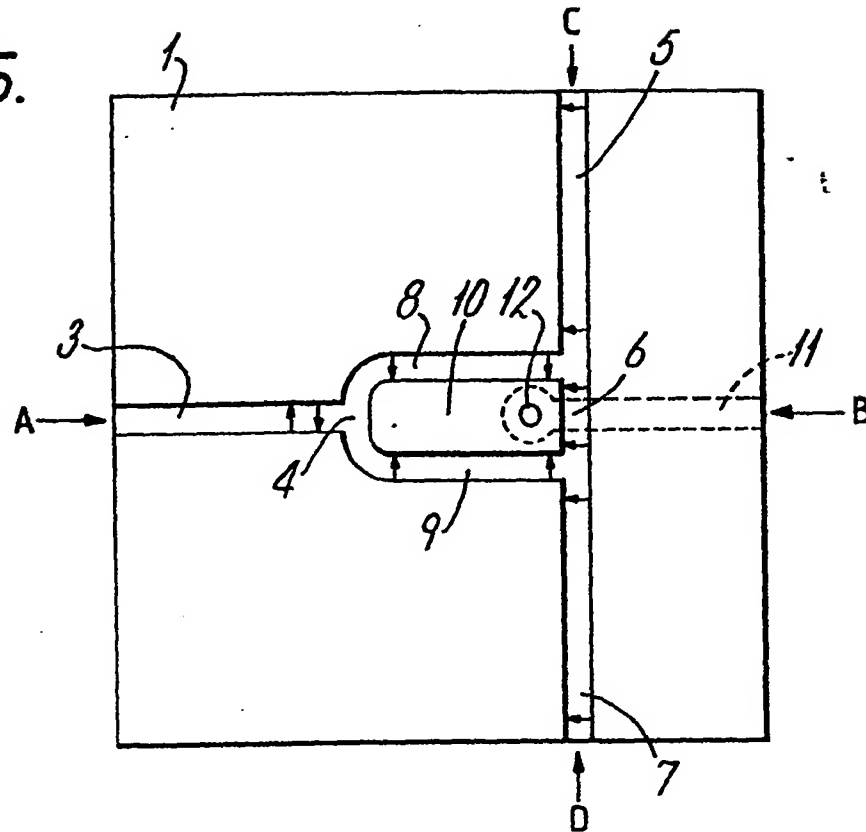


Fig. 6.

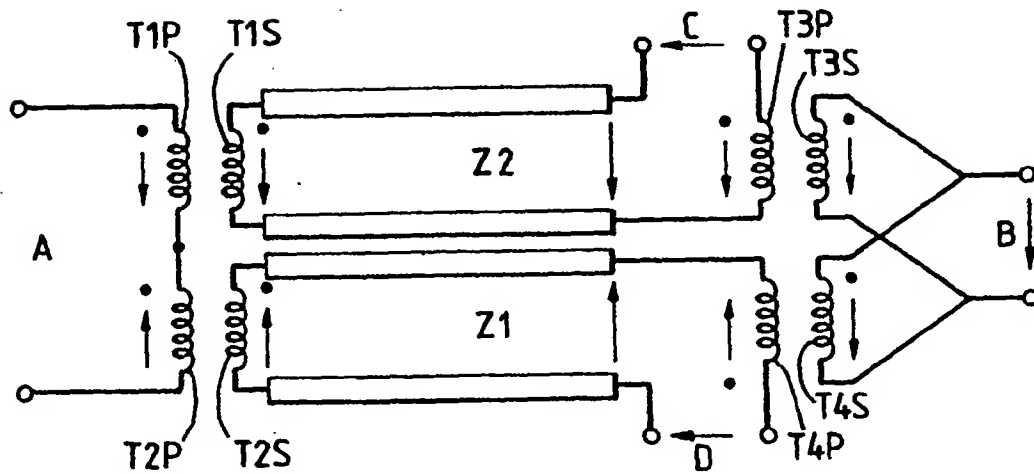
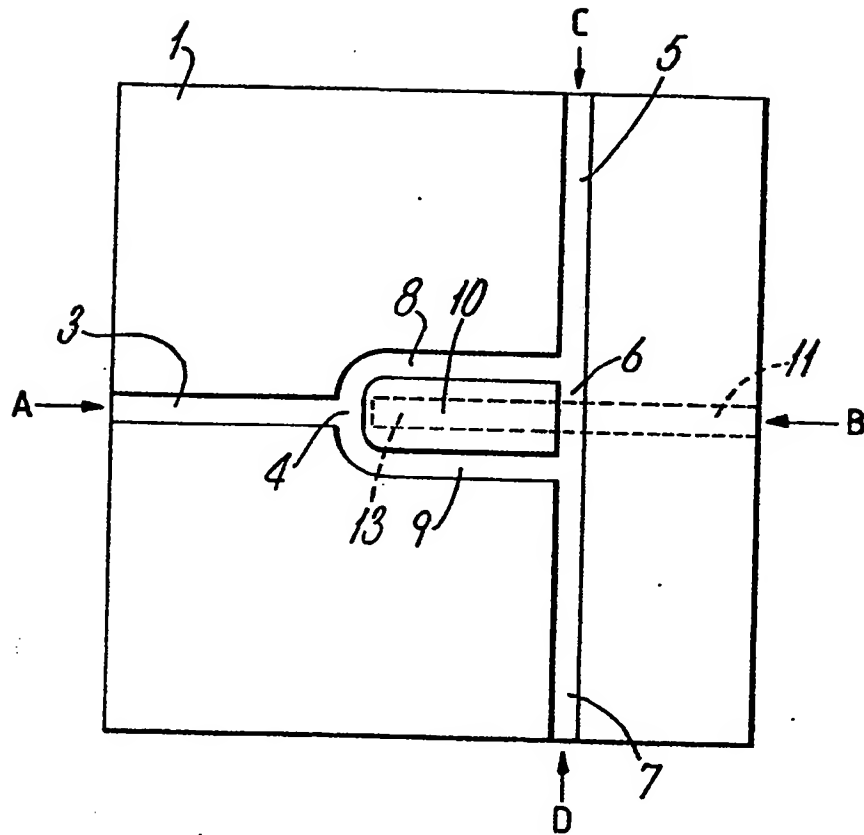


Fig. 7.



SPECIFICATION

Four-port microwave hybrid coupler

5 This invention relates to the type of four-port microwave hybrid coupler known as a 180° hybrid or Magic-Tee coupler. This type of coupler is a common waveguide component having two input ports and two output ports

10 which is arranged so that if a microwave signal is applied to one input port output signals of equal amplitude and in phase with one another emerge from the two output ports. The fourth port, the second input port, is effectively isolated if the two output ports are correctly terminated. However, if the signal is applied to the other input port, the signals at the two output ports are of equal amplitude but in anti-phase.

20 Whilst hollow waveguides are in common use, certain of the higher frequency bands in the microwave spectrum lend themselves to the use of other forms of waveguide. One of these is the stripline, in which the waveguide or the component is formed by conducting areas on one side of an insulating layer with a ground plane conducting layer on the other side. An alternative form is the slotline, where the waveguide is formed by slots in a conducting layer carried on an insulating layer.

25 Each of these forms of waveguide has its different characteristics and is best suited for use in particular situations. For example, the behaviour of the electric fields at junctions in the two types of waveguide differ. In stripline waveguides, for example, signals on two branches of a tee are in phase with one another, whereas in slotline waveguides they are out of phase.

30 Hybrid couplers are known which use a combination of stripline and slotline but are not suitable for use in all applications, and it is an object of the invention to provide a coupler which has advantages over known types in certain situations.

35 According to the present invention there is provided a four-port hybrid coupler comprising a layer of conducting material carried on one surface of an insulating support, a first slotline

40 formed in said conducting layer and having one end connected to a first input port, a second slotline formed in the conducting layer substantially at right-angles to and spaced from the other end of said first slotline and

45 connected at its ends to first and second output ports, third and fourth slotlines formed in the conducting layer each substantially an odd multiple of quarter-wavelengths long and extending from said other end of the first slotline to spaced points on the second slotline separated by a distance which is electrically small compared with one-quarter of a wavelength, and a stripline conductor carried on the other surface of the insulating support

and input port to an area directly opposite to that area of the conducting layer between the second, third and fourth slotlines.

The invention will now be described with reference to the accompanying drawings, in which:—

Figure 1 is an isometric view of a coupler according to a first embodiment of the invention;

75 *Figure 2* is a plan view of the coupler of *Fig. 1*;

Figure 3 illustrates the operation of the coupler of *Fig. 2* in a first mode;

80 *Figure 4* is an equivalent circuit of the arrangement of *Fig. 3*;

Figure 5 illustrates the operation of the coupler of *Fig. 2* in a second mode;

Figure 6 is an equivalent circuit of the arrangement of *Fig. 5*; and

85 *Figure 7* is a plan view of a coupler according to a second embodiment.

Referring now to *Figs. 1* and *2*, the coupler is made up from a layer of conducting material 1 carried on an insulating supporting board 2. Slots are cut through the conducting layer 1 to form a pattern of slotlines. A first slotline 3 extends inwards from a first input port A on the edge of the board. A second slotline extends across the board at right angles to the first slotline 1 and spaced from its inner end 4. As shown in *Fig. 2* various parts of the second slotline are given references 5, 6 and 7. The ends of the second slotline are connected to first and second output ports C and D.

From the inner end 4 of the first slotline 3, third and fourth slotlines 8 and 9 of equal length extend to meet the second slotline so that the part 6 of the second slotline is that between the junction with slotlines 8 and 9. The slotlines 8 and 9 are each an odd number of quarter-wavelengths long at the desired operating frequency and, in this embodiment, extend substantially parallel to one another.

110 The area of the conducting layer 1 between slotlines 6, 8 and 9 is given the reference 10. On the other side of the insulating layer 2 a stripline conductor 11 is formed parallel with the first slotline 3. The stripline 11 extends from the second input port B and under the area 10 of the conducting layer. A conducting connection 12 is made from an enlarged pad at the inner end of the stripline to the conducting area 10. This connection may be made by a conducting pin or by means of a plated-through hole.

The conducting layer 1 forms the ground plane for the stripline conductor 11.

125 The operation of the coupler detailed above will now be described with reference to *Figs. 3* to *6*. In the equivalent circuits of *Figs. 4* and *6*, a matched slotline series junction such as that between slotlines 3, 8 and 9 is repre-

series and having their secondary windings T1S and T2S also connected in series. The two quarter-wave slotlines 8 and 9 are represented by transmission lines Z1 and Z2. The slotline-to-stripline transition is represented by a pair of transformers having separate primary windings T3P and T4P, and having their secondary windings T3S and T4S connected in parallel. For the purposes of the following description it is assumed that all ports are correctly terminated, and any coupling between the quarter-wave slotlines 8 and 9 is neglected.

Fig. 3 illustrates the electric fields existing in the coupler when an input signal is applied to port A. The signal propagates along the first slotline 3 to the junction 4. Here it divides to form two equal-amplitude anti-phase signals in slotlines 8 and 9. At the other ends of slotlines 8 and 9 the situation is repeated; for example at the junction with parts 5 and 6 of the second slotline equal-amplitude anti-phase signals are produced in the slotline parts 5 and 6. Anti-phase outputs are therefore produced at output ports C and D. In part 6 of the second slotline, if this is short compared with a quarter-wavelength then the signals produced from the two junctions cancel one another out. Hence there is no coupling to the stripline 11 and no signal is presented to it.

Figure 4 shows the electrical equivalent circuit of the situation just described. In this case the arrows indicate instantaneous voltages at various parts of the circuit. As shown, a voltage at port A is divided equally between the primary windings T1P and T2P, resulting in equal secondary voltages across windings T1S and T2S. These voltages are prepropagated along the two identical transmission lines Z1 and Z2 to ports C and D. The voltages developed across the secondary windings T3S and T4S are of equal amplitude but of opposite phase, due to the different winding senses of primary windings T3P and T4P. The secondary voltages therefore cancel out so that there will be no voltages applied to port B. Due to the cancellation of the secondary voltages the primary windings T3P and T4P appear as short circuits, so that the input from port A divides into equal-amplitude anti-phase outputs from ports C and D.

Figs. 5 and 6 illustrate the situation which exists when the input is applied to port B. The signal connected to area 10 of the conducting layer produces a field across the part 6 of the second slotline. This feeds equal-amplitude in-phase signals to slotlines 5, 7, 8 and 9, the first two feeding output ports C and D. The signals in slotlines 8 and 9 converge at the junction 4 where they are in anti-phase and cancel out. Hence no field exists across slotline 3 and no signal is presented to port A.

plied to both of the windings T3S and T4S, now acting as primary windings.

The voltage induced in the winding T3P will be divided between port C and the input to transmission line Z2, and similarly the voltage induced in winding T4P is divided between port D and the input to transmission line Z1. The voltages applied to the transmission lines feed the windings T1S and T2S to induce equal-amplitude anti-phase voltages in windings T1P and T2P. Hence no voltage appears at port A.

The above descriptions relate to the case where the two slotlines 8 and 9 are parallel to one another for most of their length. This is necessary to ensure that part 6 of the second slotline is as short as possible. Ideally this part should be of zero length, which is not possible. Any increase in length of part 6 from a minimum possible value inevitably degrades isolation between ports C and D and consequently matching at ports A and B. The same problems will occur if the two slotlines 8 and 9 differ in length from an odd number of quarter-wavelengths or were of different lengths, as would occur if the first and second slotlines were not at right-angles. Hence it is necessary to trade-off changes in dimensions against efficiency of the coupler.

An alternative embodiment, shown in Fig. 7, avoids the need for the electrical connection between stripline 11 and the conducting layers on the other side of the board. Instead, the stripline has an end portion 13 which extends under the area 10 of the conducting layer. The length of this end portion extending beyond the second slotline joining output ports C and D should be one-quarter of a wavelength. This open-circuit stub has the same effect as the electrical connection of the previous embodiment in coupling the signal from port B into output ports C and D.

Fig. 1 shows the coupler made in the form of a rectangular board with the four ports located at its edges. In practice, however, the coupler is more likely to be made on a larger board with internal terminations either by discrete components or by transitions to other configurations such as microstrip or coplanar waveguide. However, one advantage of the coupler described is that it is considerably smaller than the majority of known couplers.

CLAIMS

1. A four-port hybrid coupler comprising a layer of conducting material carried on one surface of an insulating support, a first slotline formed in said conducting layer and having one end connected to a first input port, a second slotline formed in the conducting layer substantially at right-angles to and spaced from the other end of said first slotline and connected at its ends to first and second out-

- multiple of quarter-wavelengths long and extending from said other end of the first slotline to spaced points on the second slotline separated by a distance which is electrically small compared with one-quarter of a wavelength, and a stripline conductor carried on the other surface of the insulating support and extending parallel to the first slotline from a second input port to an area directly opposite to the area of the conducting layer between the second, third and fourth striplines.
2. A coupler as claimed in Claim 1 in which the stripline conductor is electrically connected through the insulating support to that area of the conducting layer between the second, third and fourth striplines.
3. A coupler as claimed in Claim 2 in which the electrical connection is effected by a plated-through hole.
4. A coupler as claimed in Claim 1 in which the stripline conductor carries at its end a quarter-wave stub positioned opposite to that area of the conducting layer between the second, third and fourth slotlines.
5. A coupler as claimed in any one of Claims 1 to 4 in which the third and fourth slotlines extending substantially parallel to one another.
6. A four-port hybrid coupler substantially as herein described with reference to the accompanying drawings.